Invertebrate biomass: associations with lesser prairie-chicken habitat use and sand sagebrush density in southwestern Kansas

Brent E. Jamison, Robert J. Robel, Jeffrey S. Pontius, and Roger D. Applegate

Abstract Invertebrates are important food sources for lesser prairie-chicken (*Tympanuchus pallidicinctus*) adults and broods. We compared invertebrate biomass in areas used and not used by lesser prairie-chicken adults and broods. We used radiotelemetry to determine use and non-use areas in sand sagebrush (*Artemisia filifolia*) prairie in southwestern Kansas and sampled invertebrate populations during summer 1998 and 1999. Sweepnet-collected biomass of short-horned grasshoppers (Acrididae) and total invertebrate biomass generally were greater in habitats used by lesser prairie-chickens than in paired non-use areas. We detected no differences in pitfall-collected biomass of Acrididae (P=0.81) or total invertebrate biomass (P=0.93) among sampling areas with sand sagebrush canopy cover of 0 to 10%, 11 to 30%, and >30%. Results of multivariate analysis and regression model selection suggested that forbs were more strongly associated with invertebrate biomass than shrubs, grasses, or bare ground. We could not separate lesser prairie-chicken selection for areas of forb cover from selection of areas with greater invertebrate biomass associated with forb cover. Regardless of whether the effects of forbs were direct or indirect, their importance in sand sagebrush habitat has management implications. Practices that maintain or increase forb cover likely will increase invertebrate biomass and habitat quality in southwestern Kansas.

Key words *Artemisia filifolia*, invertebrate biomass, Kansas, lesser prairie-chicken, sand sagebrush, *Tympanuchus pallidicinctus*

The lesser prairie-chicken (*Tympanuchus pallidicinctus*) is restricted to the southern Great Plains of North America, and its population has experienced dramatic range-wide declines since the 1800s (Taylor and Guthery 1980, Giesen 1998). In Kansas, lesser prairie-chickens occur in mixed and shortgrass prairies in the southwestern part of the state and are primarily found in rolling sandhills dominated by sand sagebrush (*Artemisia filifolia*, Horak 1985). Since the 1960s, numbers of lesser prairie-chickens in Kansas have declined in conjunction with habitat degradation and loss due to

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expansion of intensive agriculture, primarily center-pivot irrigation systems (Jensen et al. 2000). Declining lesser prairie-chicken populations resulted in a petition in 1995 to list the species as threatened under provisions of the Endangered Species Act. In 1996, a multi-state working group was formed to develop a conservation strategy for lesser prairie-chickens, and this group highlighted the importance of sand sagebrush habitat for conserving the species in Kansas (Mote et al. 1999).

Jamison (2000) suggested that the reproductive period (summer) was the main period limiting lesser prairie-chicken populations in remaining fragmented sand sagebrush habitats of southwestern Kansas. Invertebrates are important food sources for Galliformes during summer (Hill 1985, Dahlgren 1990, Griffon et al. 1997) and are the principal summer food of lesser prairie-chickens (Schwilling 1955; Jones 1963*a*, 1964; Davis et al. 1980). Invertebrate biomass varies with the composition and structure of vegetation (Southwood and Cross 1969, Evans 1988, Baines et al. 1996). However, despite the importance of invertebrates, little is known about invertebrate biomass in lesser prairie-chicken habitats or the relationship between sand sagebrush density and invertebrate biomass during summer. Such knowledge is critical to the successful management of summer habitat for lesser prairie-chickens.

We conducted this study to determine 1) whether lesser prairie-chicken habitat use was associated with invertebrate biomass during summer and 2) whether invertebrate biomass varied with sand sagebrush density.

Study area

We conducted fieldwork during summer 1998 and 1999 on a 5,760-ha fragment of sand sagebrush rangeland in Finney County in southwestern Kansas. The area was vegetated primarily by sand sagebrush, blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), paspalum (*Paspalum* spp.), bluestem grasses (*Andropogon* spp.), western ragweed (*Ambrosia psilostachya*), sunflowers (*Helianthus* spp.), and Russian thistle (*Salsola iberica*). Prickly pear cactus (*Opuntia* spp.) and soapweed yucca (*Yucca glauca*) were interspersed throughout the study area. Buffalo-gourd (*Cucurbita foetidissima*) and purple poppy mallow (*Callirhoe* sp.) were common in disturbed areas. Soils were in the Tivoli-Vona association and in the choppy sands range site category (United States Department of Agriculture 1965).

The area received an average of 50 cm of annual precipitation, with 74% occurring between March and August. During our study, the area received average annual precipitation of 55 cm (United States Department of Commerce 2002).

Methods

We determined use areas from locations of transmitter-equipped lesser prairie-chickens. We captured birds using walk-in traps on leks in spring or fall, fitted them with 12-g necklace-style transmitters, and released them at the capture site. We located radio-marked birds by triangulation once per day on a systematic schedule to obtain approximately equal numbers of locations during each third of daylight hours. To delineate use areas, we used the daily radio locations for adult birds, or hens with their brood, for 5 to 7 days prior to the date on which we sampled invertebrates. We plotted each location on a 1:24,000-scale topographic map and drew minimum convex polygons around the 5 to 7 locations for each bird. We treated overlapping polygons as a single use area (i.e., we sampled each use area only once during a sampling period, irrespective of how many birds it represented). We considered any area outside the use area polygons to be a non-use area. These mutually exclusive definitions of use and non-use areas were temporal in nature because lesser prairie-chickens may have frequented non-use areas >10 days before or after invertebrate sampling was conducted. Unmarked

Sweepnet operator collects invertebrates in the sand sagebrush prairie of southwestern Kansas, 1999.

birds also may have visited both use and non-use areas, but field observations during invertebrate sampling did not indicate presence of birds in non-use areas.

Invertebrate biomass in use and non-use areas

We used sweepnet sampling to obtain an index of invertebrate biomass in use and paired non-use areas of adult lesser prairie-chickens and hens with broods (hereafter broods). For each use area, we sampled invertebrates in a paired, randomly selected non-use area located within 200–800 m of the outside edge of the use-area polygon (Ratti and Garton 1996).

We collected invertebrates in use and non-use areas during 3 sampling periods over 2 years. In 1998, we sampled invertebrates in 11 (9 adult and 2 brood) use areas in July. In 1999 we sampled invertebrates in 10 (3 adult and 7 brood) use areas in June and 11 (6 adult and 5 brood) use areas in July. Samples collected in brood use areas in July 1999 were based on locations of 5 of the 7 broods that contributed locations for areas sampled in June 1999. Three of the 6 adult use areas sampled in July 1999 were determined from locations of the 3 individuals that provided locations for June use areas. We conducted sweepnet sampling of use and associated non-use areas consecutively on the same day during the first or last 3 hours of daylight to reduce time-related bias and to coincide with probable times of greatest lesser prairie-chicken foraging activity (Evans et al. 1983). We collected each sample with 100 sweeps of standard 30-cm insect nets through the upper layer of vegetation along 2 parallel 75-m transects spaced 10 m apart in each use area and paired non-use area. Each 100 sweeps in an area composed a single biomass sample for that area. We euthanized captured invertebrates in jars containing ethyl acetate, oven-dried them at 60°C for 7 days, and determined their mass. Masses of Acrididae were determined separately from other taxa because they were known to be important summer foods of lesser prairie-chickens (Schwilling 1955, Jones 1963*a*, Davis et al. 1980).

Invertebrate biomass and vegetation structure

Because resource managers may not have the time or resources to engage in formal vegetation sampling, we chose to sample areas easily categorized into one of 3 broad sagebrush canopy categories. Sand sagebrush canopy cover ranged from 0 to slightly over 50% on our study area. Using a black-and-white low-altitude aerial photograph in conjunction with our prior knowledge of variation in sagebrush canopy across the study area, we arbitrarily chose 5 areas each of low (<11%), moderate (30%), and high (>30%) sagebrush canopy cover, which were spaced throughout the study area. Generally, darker areas on the photograph represented areas of higher canopy cover, and lighter areas depicted lower canopy cover.

We collected invertebrate samples and vegetation structure data in each area during June 1998. We captured invertebrates using 25 × 25-m grids of pitfall traps (9 traps per grid). Pitfall traps had 9.8-cm-diameter top openings with 4 15-cm guides (drift fences) to increase trap efficacy (Morrill et al. 1990). We used Ethylene glycol as the killing agent. Pitfall traps were open for 5 days in each of the 15 grids. We rinsed collected invertebrates in water, sorted them to family (except some larval forms and representatives of the orders Lepidoptera and Homoptera), and oven-dried them at 60°C for 7 days prior to determining their masses.

Additionally, we estimated percentage bare ground and canopy cover of shrubs, grasses, and forbs using a line-point sampling strategy (Heady et al. 1959). We recorded occurrence of each vegetation type along 3 evenly spaced 25-m transects in each pitfall trapping grid. We placed one vegetation transect 1 m east of each north-south line of pitfall traps within the sampling grids. Vegetation type recorded at 0.5-m intervals on each transect (153 sample points per grid) was the basis for estimating percentage bare ground and canopy cover of shrubs, grasses, and forbs. We recorded vegetation measurements immediately following the 5-day trapping period.

Data analysis

We compared sweepnet-collected Acrididae and total invertebrate biomass between use and non-use areas for each sampling period using one-sample *t*-tests of mean differences between use and non-use pairs. Biomass data for adult use areas and brood use areas were pooled when analyzed by sampling period. We also separately analyzed data for adult use areas and brood use areas but pooled them across sampling periods because of small sample sizes. Three adults and 5 hens with broods contributed location data used to delineate use areas in both June and July 1999. We analyzed

Table 1. Percentage of total variance explained and factor loadings for principal components and correlation matrix for percentage of each cover type in 15 invertebrate trapping grids in southwestern Kansas, 1998.

Principal component and cover type	Percent variance explained	Cover type: Shrub	Grass	Forb	Bare ground
PC1	79.2	0.90	−0.98	0.22	0.88
PC2	14.4	−0.38	0.03	0.86	0.41
PC3	3.5	0.22	0.21	0.15	0.10
PC4	2.8	0.08	−0.05	0.10	−0.21
Shrub		1.00	−0.84	−0.07	0.64
Grass			1.00	−0.18	−0.82
Forb				1.00	0.47
Bare ground					1.00

biomass data from these samples as unique pairs of use and non-use areas because they were separated in time by about one month, and spatially distinct use and paired random non-use areas were defined for each sampling period.

We compared pitfall-collected invertebrate biomass data among the 3 sand sagebrush canopy coverage categories using a one-way analysis of variance. We also examined relationships between all cover types (shrubs, grass, forbs, and bare ground) and invertebrate biomass using a 2-step multiple regression approach. Because original vegetation variables were correlated (Table 1), we used principal components analysis (Manly 1986) to derive uncorrelated vegetation variables. We then regressed invertebrate biomass on vegetation principal components. Principal components were calculated from the covariance matrix, and factor loadings were computed to identify relationships between original vegetation variables and principal components.

Biomass data for 8 invertebrate taxa and total biomass were regressed on vegetation principal components. We used Akaike's Information Criterion corrected for use with small sample sizes (AIC_c) to select the least biased, most parsimonious model that described the structure in the data (Burnham and Anderson 1998). We determined relative importance of each of the principal components in predicting invertebrate biomass from the sums of AIC_c model weights for each model in which a particular principal component appeared. We conducted all statistical procedures using SAS (SAS Institute 1996).

Results

Invertebrate biomass in use and non-use areas

Sweepnet sampling provided indices of invertebrate biomass in 18 adult lesser prairie-chicken and 14 brood use and 32 paired non-use areas. Acrididae biomass ranged from 2.44-13.0 g/sample in use areas and from 0.09-9.03 g/sample in non-use areas. Total biomass ranged from 2.96-13.5 g/sample in use areas and 0.14-9.09 g/sample in non-use areas. Acrididae biomass constituted 93-95% of the total sweepnet-collected invertebrate biomass in July 1998, 72-81% in June 1999, and 84-90% in July 1999.

In 72% of the 32 pairs of sweepnet samples, Acrididae biomass was greater in the use area than in the non-use area. Total biomass was greater in use area samples in 69% of the 32 pairs. Acrididae and total invertebrate biomass collected in use areas were greater than in non-use areas in all 3 sampling periods (July 1998, June 1999, and July 1999; Table 2). Separate analyses of sweepnet-collected invertebrate biomass from adult and brood use and non-use areas also showed greater invertebrate biomasses in use areas (Table 3), but in most cases small sample sizes prevented detection of statistically significant differences.

Table 2. Mean (SE) Acrididae and total invertebrate biomass (g/sample) in all lesser prairie-chicken (adult and brood) use and paired non-use areas, collected during summer in southwestern Kansas, 1998–1999.

Year and period	*n*	Taxon	Use	Non-use	Difference	*t*	*P*[a]
1998							
July	11	Acrididae	7.22 (0.88)	5.76 (0.86)	1.46 (0.86)	1.69	0.122
		Total	7.78 (0.97)	6.08 (0.87)	1.70 (0.96)	1.77	0.106
1999							
June	10	Acrididae	2.66 (0.48)	1.15 (0.17)	1.50 (0.40)	3.76	0.005
		Total	3.29 (0.47)	1.59 (0.20)	1.70 (0.42)	4.04	0.003
July	11	Acrididae	5.44 (0.68)	4.96 (0.52)	0.48 (0.79)	0.61	0.555
		Total	6.08 (0.73)	5.93 (0.62)	0.15 (0.88)	0.17	0.866

[a] *P*-value is for test of H_0: $\mu = 0.0$.

Table 3. Mean (SE) Acrididae and total invertebrate biomass (g/sample) in lesser prairie-chicken adult and brood use and paired non-use areas, collected during summer in southwestern Kansas, 1998–1999.

Samples	n	Taxon	Use	Non-use	Difference	t	P^a
Adult	18	Acrididae	5.18 (0.61)	4.31 (0.68)	0.87 (0.58)	1.49	0.154
		Total	5.74 (0.64)	4.69 (0.67)	1.04 (0.63)	1.65	0.116
Brood	14	Acrididae	5.19 (0.92)	3.70 (0.72)	1.48 (0.60)	2.47	0.028
		Total	5.86 (0.95)	4.53 (0.82)	1.33 (0.73)	1.82	0.092

[a] P-value is for test of H_0: $\mu = 0.0$.

Invertebrate biomass and vegetation structure

Mean biomass of invertebrates captured in pitfall traps ranged from 1.24–2.67 g/trap in areas of low sagebrush canopy cover, 1.08–4.27 g/trap in moderate cover, and 1.41–2.43 g/trap in areas of high sagebrush canopy cover. Representatives of Carabidae (ground beetles) composed 30.7% of pitfall-collected biomass, Gryllacrididae (camel crickets) 24.1%, Acrididae (short-horned grasshoppers) 20.1%, and Tenebrionidae (darkling beetles, primarily *Eleodes* spp.) 19.7%. Formicidae (ants) and Lepidoptera (butterflies and moths) made up 3.7 and 1.3% of the pitfall-collected biomass, respectively. Homoptera (cicadas, leaf hoppers, etc.) and Chrysomelidae (leaf beetles) each composed 0.2% of the biomass.

Mean biomass of pitfall-collected Acrididae ranged from 0.24–0.33 g/trap among areas with low, moderate, and high sand sagebrush canopy cover, and were similar among canopy cover categories (Table 4). Mean biomass of all invertebrates collected in pitfall traps (total invertebrate biomass) ranged from 1.87–2.07 g/trap among sand sagebrush canopy categories, but also were similar among sagebrush canopy categories.

Principal components analysis revealed strong associations among original vegetation variables (Table 1). Shrub canopy and bare ground were positively correlated (r = 0.64), and both were negatively correlated with grass cover (r=-0.84 and -0.82, respectively). Forb cover was weakly associated with percent bare ground cover(r = 0.47). Shrub and bare ground both loaded highly (0.90 and 0.88, respectively) on the first principal component (PC1), which explained about 79% of the variation in vegetation structure among pitfall grids. Forb cover loaded highly (0.86) on the second principal component (PC2), which explained an additional 14% of the variability in vegetation structure (Table 1, Figure 1).

Table 4. Mean (SE) biomass (g/pitfall trap) of Acrididae and total invertebrate biomass collected in 5 areas each of low (0–10%), moderate (11–30%), and high (>30%) sand sagebrush canopy cover in southwestern Kansas during June, 1998.

	Sagebrush canopy cover				
	Low (n = 5)	Moderate (n = 5)	High (n = 5)	F	P
Acrididae	0.33 (0.11)	0.24 (0.12)	0.28 (0.04)	0.21	0.81
Total	3.37 (0.73)	2.79 (0.77)	2.38 (0.20)	0.64	0.54

The selected best regression models varied among taxa and did not fit the data well (Tables 5 and 6). The model incorporating only PC2 was the selected best model for most (5 of 8) individual taxa and total invertebrate biomass, and the model with only PC1 was selected as the best model for Homoptera, Tenebrionidae, and Lepidoptera. The model with both variables never was the selected best model.

PC2 was a more important predictor of biomass than PC1 (Table 6). Biomass of Acrididae, Gryllacrididae, Chrysomelidae, Carabidae, and Formicidae were more dependent upon PC2 than PC1, and PC2 was nearly 3 times more important than PC1 in predicting total invertebrate biomass.

Relationships between Acrididae, Carabidae, Chrysomelidae, and total invertebrate biomass and PC2 were stronger than those for other taxa, and the relationship between Formicidae and PC2 appeared to be driven by a single outlier (Table 6, Figure 2). The relationship between Tenebrionidae and PC1 was stronger than for other taxa for which PC1 was a more important predictor of biomass, but all 3 of these relationships were weak and noisy. Relationships for Homoptera and Lepidoptera also appeared to be driven by single aberrant biomass values (Figure 3).

Discussion

Results of comparisons between invertebrate biomass collected in use and non-use areas of adults and broods suggest that lesser prairie-chickens select areas with greater Acrididae and total

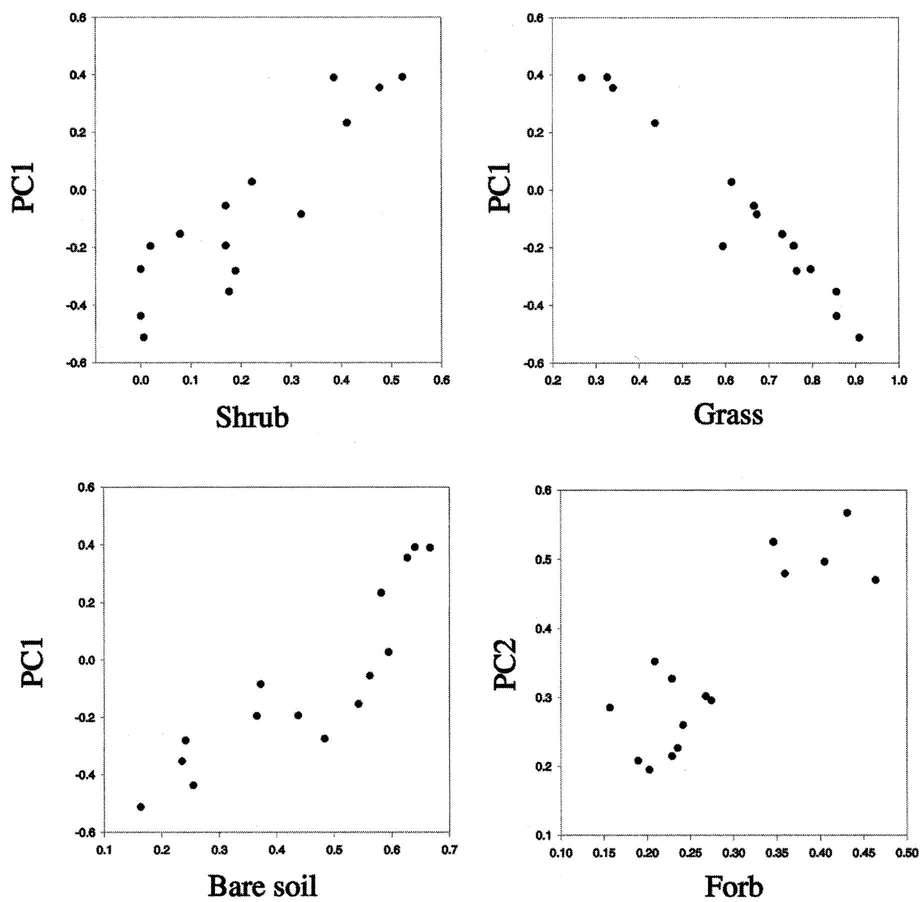

Figure 1. Selected relationships between original vegetation variables (% cover) and principal components, southwestern Kansas 1998.

invertebrate biomass than surrounding areas.

It is possible that lesser prairie-chickens in this study selected sand sagebrush habitat based on the vegetation structure and that greater invertebrate biomass was simply associated with selected vegetation structure. For example, lesser prairie-chickens may select habitats that provide shade during hot, dry weather (Copelin 1963), or they may select areas based directly on the abundance of forbs, which also are consumed (Jones 1964, Riley et al. 1993, Giesen 1998). Sand sagebrush shrubs were the primary source of shade on our study area; however, we did not find greater invertebrate biomass in areas of greater sand sagebrush density, and

Table 5. ΔAIC_c values for 3 models expected to predict biomass of 8 individual taxa and total biomass collected in 15 pitfall trapping grids in sand sagebrush habitats of southwestern Kansas in 1998. Model with ΔAIC_c = 0.00 is selected best model; parenthetical numbers are AIC_c model weights.

	Taxon								
Variables in model	Acrididae 2.53[a]	Gryllacrididae 3.06	Homoptera 0.02	Chrysomelidae 0.03	Tenebrionidae 2.48	Carabidae 3.87	Formicidae 0.47	Lepidoptera 0.17	Total 17.73
PC1[b]	2.15 (0.19)	0.18 (0.40)	0.00 (0.64)	8.63 (0.01)	0.00 (0.43)	5.96 (0.04)	1.67 (0.25)	0.00 (0.45)	4.65 (0.07)
PC2	0.00 (0.55)	0.00 (0.44)	4.87 (0.06)	0.00 (0.68)	0.69 (0.30)	0.00 (0.76)	0.00 (0.58)	0.21 (0.41)	0.00 (0.68)
PC1, PC2	1.50 (0.26)	1.99 (0.16)	1.49 (0.30)	1.54 (0.31)	0.80 (0.28)	2.64 (0.20)	2.39 (0.17)	2.37 (0.14)	1.94 (0.26)

[a] Mean biomass (g) per pitfall grid collected in 15 trapping grids.

[b] PC1 (principal component 1) is interpreted as the negative correlation between shrubs and bare ground versus grass cover; PC2 (principal component 2) represents primarily forb cover.

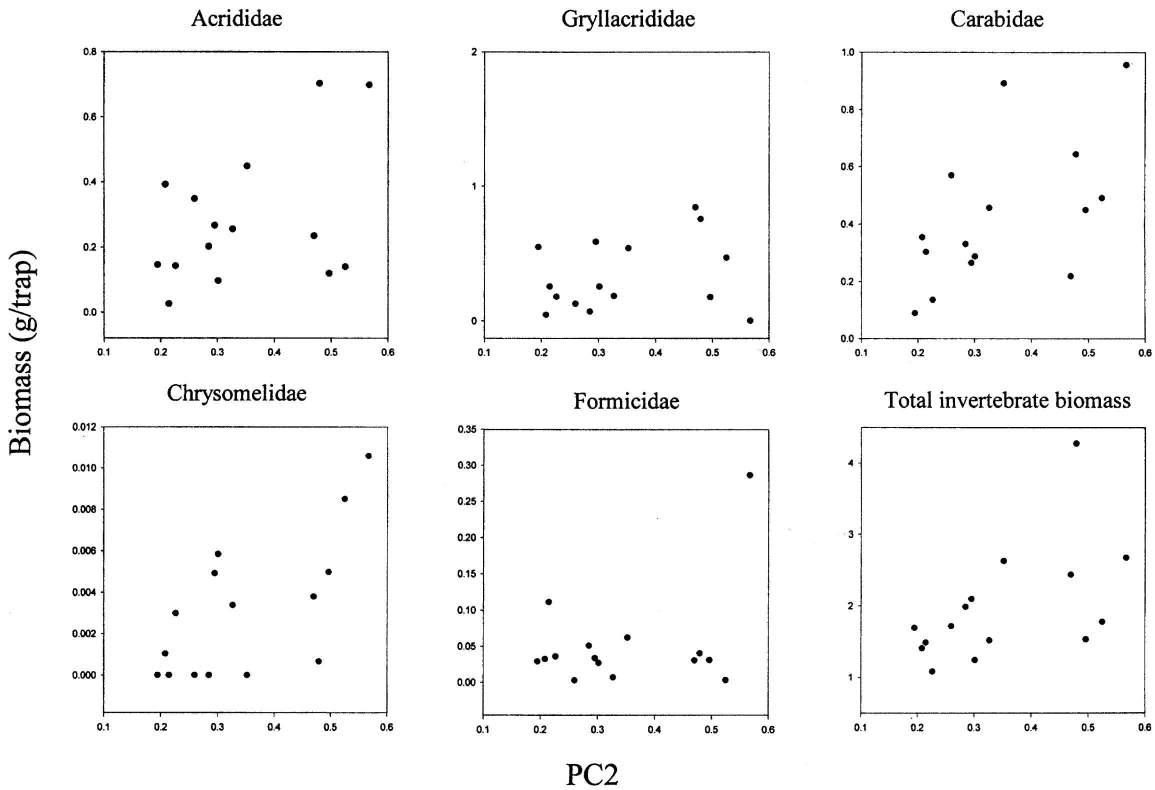

Figure 2. Relationships between invertebrate biomass and vegetation principal component 2 (PC2) for taxa for which PC2 was the most important predictor of biomass.

Table 6. Relative importance of cover principal components (sums of AIC_c model weights) and parameter estimates and regression coefficents for the selected best model of biomass for 8 individual taxa and total invertebrate biomass in 15 trapping grids in southwestern Kansas, 1998.

	Sums of AIC_c model weights			
Taxon	PC1[a]	PC2	Slope[b]	R^2
Order Orthoptera				
Acrididae	0.45	0.81	0.698	0.187
Gryllacrididae	0.56	0.60	0.495	0.055
Order Homoptera	0.94	0.36	–0.008	0.315
Order Coleoptera				
Chrysomelidae	0.32	0.99	0.018	0.460
Tenebrionidae	0.70	0.57	0.269	0.143
Carabidae	0.24	0.96	1.136	0.330
Order Hymenoptera				
Formicidae	0.42	0.75	0.191	0.121
Order Lepidoptera	0.59	0.54	0.023	0.035
Total biomass	0.32	0.93	3.394	0.292

[a] PC1 (principal component 1) is interpreted as the negative correlation between shrubs and bare ground versus grass cover; PC2 (principal component 2) represents primarily forb cover.

[b] Slope and R^2 are for model with the variable having the greater sum of AIC_c model weights.

regression modeling suggested shrubs were the least important determinants of invertebrate biomass. Because forb abundance appeared to be positively associated with invertebrate biomass, we could not separate whether habitat selection was due to forb abundance or invertebrate biomass. However, forbs and other plant matter generally compose about 30% of the lesser prairie-chicken's summer diet and invertebrates constitute up to 70% (Schwilling 1955, Jones 1963*b*). Based on the relationship between invertebrate biomass and sagebrush cover and summer diet information, invertebrate abundance likely influenced habitat selection more than forb abundance. Use of areas with greater invertebrate biomass suggests that invertebrate biomass in sand sagebrush habitats is an important component of lesser prairie-chicken habitat quality.

Of the vegetation structure variables that were examined, forb cover was most strongly associated with biomass of invertebrates present in the habitat. None of the areas selected for sampling was dominated by forbs. Had we selected sampling areas with greater forb cover, we suggest the

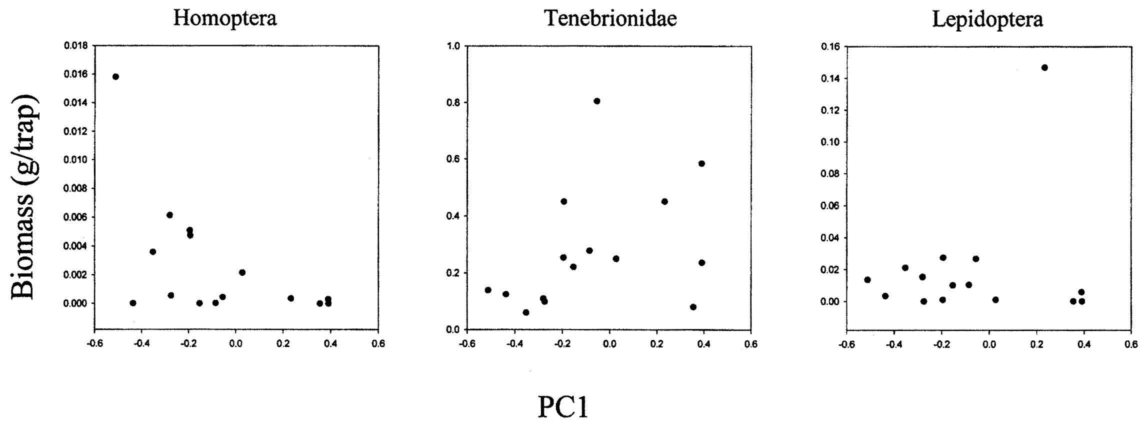

Figure 3. Relationships between invertebrate biomass and vegetation principal component 1 (PC1) for taxa for which PC1 was the most important predictor of invertebrate biomass.

relationships between invertebrate biomass and forb cover may have been even stronger. Our conclusions support those of Jones (1963*b*), Southwood and Cross (1969), Hill (1985), Burger et al. (1993), and others that forbs are important components of Galliforme foraging habitat because they provide abundant invertebrates. Doerr and Guthery (1983) and Hull et al. (1996) reported positive but "non-significant" associations between invertebrate biomass and forb abundance, and Boyd and Bidwell (2001) reported concurrent increases in forb cover and grasshopper densities with prescribed fire. The difficulty of sampling invertebrate populations and their patchy distribution makes determination of true patterns difficult (Murkin et al. 1996), but our study adds to the accumulating evidence on the importance of forbs in determining invertebrate biomass.

Management implications

The affinity of lesser prairie-chickens for areas with greater invertebrate biomass offers management opportunities. Directly manipulating invertebrate populations probably is not possible, but managing habitat in a manner producing greater invertebrate populations may be feasible. We observed a positive association between forbs and invertebrate populations. Habitat management practices resulting in increased forb cover in sand sagebrush habitats likely will result in increased invertebrate biomass available to lesser prairie-chickens. Litton et al. (1994) suggested that strip-disking at depths of 7 to 15 cm or burning treatments conducted on flat areas of firm soil during March should produce early successional habitats dominated by native forbs. Boyd and Bidwell (2001) found that prescribed burning in spring, fall, or winter increased coverage of forbs in shinnery oak (*Quercus havardii*) habitats and also noted that forbs dominated the early successional plant community of revegetating fire breaks. Widespread and annual burning should be avoided to retain areas of residual vegetation used as nesting cover, but prescribed burns of small areas may produce ideal brood-rearing habitat. Practices aimed at reducing cover of native forbs (e.g., intensive herbicide treatment) may negatively influence habitat quality by reducing standing crops of important invertebrate and plant food taxa (Doerr and Guthery 1983).

Lesser prairie-chickens require an interspersion of nesting cover and foraging areas (Jones 1964, Donaldson 1969, Taylor and Guthery 1980). The spatial distribution of forb cover may be an important element of lesser prairie-chicken habitat. The even distribution of native forbs throughout their habitat, or many small forb-dominated areas that are evenly distributed, may be more suitable than relatively large and isolated forb-dominated areas (i.e., a clumped distribution of forbs), because associated invertebrates would be available to more individual lesser prairie-chickens under the even-distribution scenario.

Lesser prairie-chicken broods are more reliant on invertebrate foods than adult birds (Giesen 1998). Management practices that improve habitat for broods may be extremely beneficial because low chick survival is an important limiting factor for lesser prairie-chicken populations in southwestern Kansas (Jamison 2000). An adequate invertebrate forage base is not the only critical element of lesser prairie-chicken habitat, and the response of lesser prairie-chickens to any management practice should be evaluated prior to implementation over large areas.

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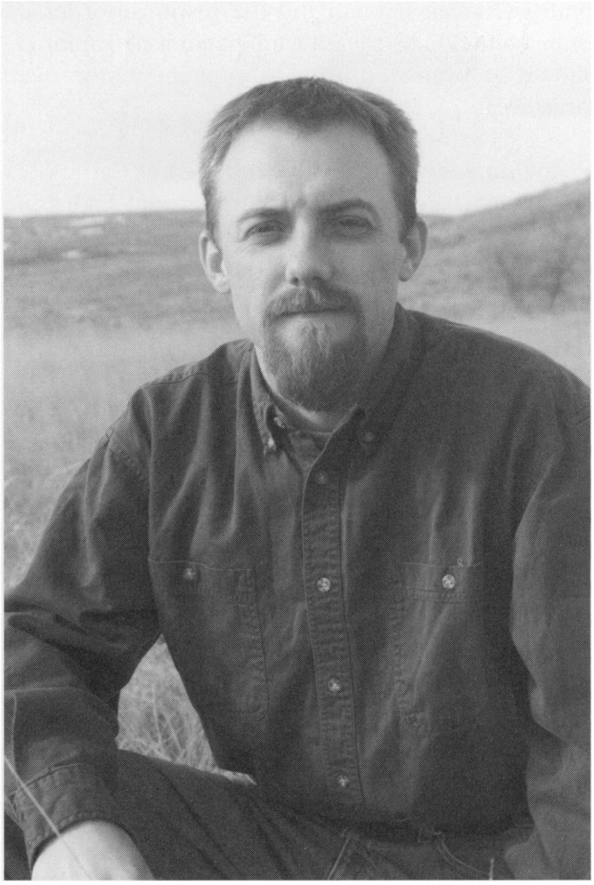

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